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Ten-Year Results of Fertilizing Grand Fir, Western Hemlock, Western Larch, and Douglas-fir with Nitrogen in Northern Idaho

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RESEARCH SUMMARY

Forest fertilization is a successful cultural treatment for increasing forest yields. However, research has shown wide variability in response of forest stands to the application of fertilizer. Results of most studies on nitrogen fertilizer, the most commonly applied nutrient, are highly dependent on site and species.

This study also shows high variability that can be expected from the application of fertilizer. Ten years after the application of nitrogen fertilizer in the form of urea at 200 and 400 lb per acre, only short-term differences in tree growth could be detected between fertilized and unfertilized trees. No major differences were evident after 10 years. Grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) had the best response to fertilizer 5 years after application with a 45 percent increase in diameter growth at that time. Fertilized western white pine (*Pinus monticola* Dougl.) were growing slower than the unfertilized pine after either 5 or 10 years. How tree species respond to the application of fertilizer may be related to their successional position in a stand and their tolerance to different ranges or levels of nitrogen nutrition.

Ten-Year Results of Fertilizing Grand Fir, Western Hemlock, Western Larch, and Douglas-fir with Nitrogen in Northern Idaho

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INTRODUCTION

Forest fertilization has become an accepted management tool for increasing merchantable volumes of forest stands in many areas of the country. However, there is reluctance to apply fertilizers operationally because of inconsistent growth responses and because of a paucity of information on the response of forest stands to fertilization, particularly in the Northern Rocky Mountains.

Nitrogen, usually the most growth-limiting nutrient of forest soils, is the most commonly applied fertilizer. The addition of other elements, such as phosphorus, potassium, and sulfur, seldom improves gains achieved from applying nitrogen alone (Gessel and others 1965; Heilman 1971; Miller and Reukema 1974). Nitrogen is usually applied in the form of urea that contains 46 percent nitrogen, or in the form of ammonium nitrate that contains 34 percent nitrogen.

The site on which fertilizer experiments are located can influence results. Usually, better growth responses to fertilizer occur on poor sites (Miller and Fight 1979). But often, as Miller and Reukema (1974) found, good sites also have excellent response to application of fertilizer. They reported ammonium nitrate applied at 300 lb per acre significantly increased growth of 75-year-old Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) on a highly productive site in western Washington. In contrast, Graham and Tonn (1979) reported no increase in growth attributable to the application of nitrogen fertilizer on western white pine (*Pinus monticola* Dougl.) on a good site in northern Idaho. Webster and others (1976) reported poor growth responses to the application of nitrogen fertilizer on western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) along the Pacific coast. On inland sites, they reported a good response.

How an individual species reacts to the application of fertilizer can also be highly variable. As noted earlier, western white pine in one study in northern Idaho did not respond to nitrogen fertilizer, while in another (Ryker and Pfister 1967) there was a 39 percent increase in the diameter growth of nitrogen-fertilized western white pine over unfertilized pine. Similarly, Loewenstein and Pitkin's study in northern Idaho (1963) reported nitrogen-fertilized western white pine with a 187 percent increase in height growth, as compared to unfertilized pine. Scanlin and others (1976) reported a 61 percent growth increase of grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) due to nitrogen fertilizer application in northern Idaho. Loewenstein and Pitkin (1963) also reported a 286 percent response to the application of nitrogen fertilizer on grand fir in northern Idaho.

As these examples show, the results of fertilizer trials are highly variable. They also show how uncertain the results from the application of fertilizers can be. Therefore, the surest way to select areas for operational fertilization is to match stand and soil characteristics of successful, experimental field trials (Miller and Fight 1979).

This study was undertaken to document the results of nitrogen fertilization in two stands on experimental forests chosen as representative of good sites in northern Idaho. We reasoned that stands of proper age, growing on sites with no likely moisture or other nutrient limitations to growth, might respond well to the application of readily available nitrogen.

STUDY DESIGN

Two fertilization studies were established in young, natural stands of mixed conifers in the *Tsuga heterophylla/Pachystima myrsinites* habitat type (Daubenmire and Daubenmire 1968). One was located at the Deception Creek Experimental Forest (DCEF), and the other was at the Priest River Experimental Forest (PREF). Both represent excellent forest sites in northern Idaho.

The DCEF study, on a north aspect, in lower Snyder Creek was 4.5 acres in size. Slope angles ranged from gentle to 50 percent. The soils of the area are inceptisols overlaying gneiss parent material. The stand developed under seed trees from a 1952 cutting. The seed trees were removed in 1965, and in 1971 the stand was cleaned to a 10-foot-square spacing. A uniform stand of dominant and codominant trees remained. Species represented in the stand included:

- western white pine
- western larch (*Larix occidentalis* Nutt.)
- Douglas-fir
- grand fir
- western hemlock
- Engelmann spruce (*Picea engelmannii* Parry ex Engelm.)
- subalpine fir (*Abies lasiocarpa* [Hook.] Nutt. var. *lasiocarpa*)

The plots at DCEF were fertilized in fall 1972. At that time the stand had a mean diameter of 1.4 inches and a mean height of 10.7 feet.

The DCEF study was designed as a randomized complete block with five blocks, each having three treatments. The treatments were randomly assigned to 0.5-acre treatment units as:

Treatment 1: no fertilization

Treatment 2: urea applied by hand spreader at the rate of 200 lb of N per acre

Treatment 3: urea applied by hand spreader at the rate of 400 lb of N per acre

Subplots of 0.04 acre were established within the treatment units, and trees within the subplots were tagged and measured.

The PREF study was on 3 acres in the lower part of the Benton Creek Drainage. The stand originated in 1955 after cutting of the previous stand and dozer clearing of the area. Slope angles ranged from 25 to 35 percent. The stand is growing on soils classified as typic cryochrept and derived from gneiss parent material. After a cleaning in fall 1971 to a 12-foot-square spacing, a uniform stand of the following species was left:

western white pine
western larch
Douglas-fir
lodgepole pine (*Pinus contorta* Dougl. ex Loud.)
western hemlock
western redcedar (*Thuja plicata* Donn ex D. Don)
Engelmann spruce
ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*)

Fertilization at PREF took place early in spring 1973. At that time, the mean stand diameter was 3.3 inches and the mean height was 21.7 feet.

At PREF a randomized complete block design was used with three blocks each having two treatments. In contrast to the DCEF study, only two treatments were randomly assigned to 0.5-acre treatment units, as follows:

Treatment 1: no fertilization

Treatment 2: urea applied by hand spreader at the rate of 200 lb of N per acre

Subplots of 0.1 acre were established within the treatment and the trees within them tagged and measured.

At both areas, diameter at breast height (d.b.h.) and total height of the tagged trees were measured in 1973, 1974, 1977, and 1982. Periodic mean annual diameter growths and periodic mean annual height growths for 1973 to 1977 and 1977 to 1982 were computed for the trees remaining in 1977 and 1982, respectively.

An analysis of covariance was used to analyze the data for each study area. Because tree size at the time of treatment influences subsequent growth, individual tree d.b.h. at the time of establishment was used as a covariate for analyses involving diameter, and individual tree height at the time of establishment was used as a covariate in the analyses involving heights. The dependent variables used in the analyses included d.b.h., height, and periodic mean annual height growth and periodic mean annual diameter growth for 0 to 5 and 5 to 10 years after treatment. Those species that had adequate observations to analyze alone included grand fir at DCEF and western white pine, western larch, and Douglas-fir at PREF. Various analysis of covariance tables were created (table 1). In all cases, if the F test in the analysis detected significant differences ($p \leq 0.05$) between the treatment means, the least squares mean separation procedure was used to locate the differences (SAS Institute 1982).

RESULTS

The results of this study reveal how mixed-species stands of conifers respond to the application of nitrogen fertilizer in northern Idaho, and how nitrogen fertilizer affects the diameter and height growth of four species. In addition, these results show the inconsistent growth responses that can be expected when applying fertilizer to forest stands.

Table 1.—Analysis of covariance

Source	Degrees of freedom						Expected mean squares
	Deception Creek Experimental Forest		Priest River Experimental Forest				
	All trees	Grand fir	All trees	Western white pine	Western larch	Douglas-fir	
Treatments	2	2	1	1	1	1	$\sigma^2 + s\sigma^2_\epsilon + sr \Sigma \tau_i^2/(t-1)$
Blocks	4	4	2	2	2	2	$\sigma^2 + s\sigma^2_\epsilon + st \Sigma \beta_i^2/(r-1)$
Block * treatment (experimental error)	8	8	2	2	2	2	$\sigma^2 + s\sigma^2_\epsilon$
Sampling error	200	96	170	16	28	69	σ^2
Covariate (initial height or initial d.b.h.)	1	1	1	1	1	1	
Total	215	111	176	22	34	75	

Deception Creek Experimental Forest

The increased growth rates brought about by application of fertilizer were short-lived. Five years after treatment, trees of all species fertilized with nitrogen had a periodic mean annual diameter growth[1] 24 percent larger than unfertilized trees (table 2). There were no significant differences ($p \leq 0.05$) in diameter growth means detected between the 200- and 400-lb-per-acre fertilizer treatments. In contrast, during the 5 to 10 years after treatment, no significant differences in diameter growth were found due to fertilization between any of the three treatments (table 2).

During the first 5 years after treatment, trees in the two fertilized treatments also had significantly ($p \leq 0.05$) larger periodic mean annual height growths than the unfertilized treatment. An 18 percent significant difference existed in the height growth means observed between unfertilized and 400-lb-per-acre treatments, but no significant difference occurred in height growth means between the two levels of fertilizer. As with diameter growth, no differences in height growth were apparent during the 5 to 10 years following treatment.

Grand fir alone had growth patterns similar to the stand as a whole. Five years after treatment, a 30 percent difference (significant at $p \leq 0.05$) in periodic mean annual diameter growth was detected between the unfertilized and 200-lb-per-acre treatments (table 2). No significant differences in the means for diameter growth were observed between the two fertilizer treatments. During the second 5 years, no significant differences between the treatment means for diameter growth were detected.

Periodic mean annual height growth for grand fir was also influenced by the application of fertilizer for only the first 5 years (table 2). There was a 45 percent difference in height growth means between the unfertilized grand firs and those treated with 400 lb per acre of nitrogen. Even though there was a 17 percent difference between height growth means for the two levels of fertilizer, the difference was not statistically significant ($p \leq 0.05$). No significant differences among the annual height growth means could be detected 10 years after treatment (table 2).

Priest River Experimental Forest

At PREF, the application of nitrogen fertilizer had little influence on tree growth. During the first 5 years after treatment, no significant differences ($p \leq 0.05$) in periodic mean annual diameter growth were found with application of fertilizer (table 3). Likewise, during the second 5 years after treatment, no significant differences were detected in diameter growth between the fertilized and unfertilized trees.

However, a significant response occurred in the fertilized trees in periodic mean annual height growth during the first 5 years after fertilization. The fertilized trees had a 9 percent larger growth mean than the unfertilized ones (table 3). As with treatments at DCEF, there were no significant differences in annual height growth means during the second 5 years after treatment.

Western white pine did not respond positively to the application of nitrogen fertilizer at PREF. Furthermore, the unfertilized western white pine actually had a larger periodic annual diameter growth mean than the fertilized pine (table 3) during the first 5 years after treatment. Neither diameter growth means nor periodic annual height growth means for the two treatments were significantly different during the first or second 5 years after treatment.

Western larch at PREF also had little response to fertilizer, similar to western white pine. No significant differences in periodic annual diameter growth means were observed either 5 or 10 years after treatment (table 3). Also, no differences in the periodic annual height growth means were detected between the fertilized and unfertilized trees.

The only species at PREF that showed a positive response to fertilization was Douglas-fir. The periodic annual height growth mean 5 years after treatment for 200-lb-per-acre was significantly larger (17 percent) than the mean for the unfertilized treatment, while 10 years after treatment, no differences in height growth were detected. No significant differences were detected

[1]All means reported are least square means adjusted by covariate analysis for initial differences at the beginning of the study.

Table 2.—Periodic mean[1] annual diameter growth and periodic mean annual height growth for all species and for grand fir at Deception Creek Experimental Forest

	All species				Grand fir			
	Diameter		Height		Diameter		Height	
Treatment[2]	0-5[3]	5-10	0-5	5-10	0-5	5-10	0-5	5-10
	Inches		*Feet*		*Inches*		*Feet*	
1	0.29a[4]	0.28a	1.14a	1.51a	0.27a	0.26a	1.10a	1.33a
2	.36b	.28a	1.25b	1.71a	.35b	.27a	1.36b	1.93a
3	.36b	.31a	1.35b	1.58a	.34b	.31a	1.59b	1.87a

[1]All means are least square means. Diameter growths are adjusted for diameter at beginning of the study and height growths are adjusted for height at the beginning of the study.
[2]Treatment 1 = no fertilizer, 2 = 200 lb N/acre, 3 = 400 lb N/acre.
[3]Time since treatment in years. There are no significant differences ($p \leq 0.05$) in the means between time periods.
[4]Different letters following means indicate significant differences ($p \leq 0.05$) between treatments.

Table 3.—Periodic mean[1] annual diameter growth and periodic mean annual height growth for all species, western white pine, Douglas-fir, and western larch at Priest River Experimental Forest

	All species				Western white pine				Douglas-fir				Western larch			
	Diameter		Height		Diameter		Height		Diameter		Height		Diameter		Height	
Treatment[2]	0-5[3]	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10
	--- Inches ---		---- Feet ----		--- Inches ---		---- Feet ----		--- Inches ---		---- Feet ----		--- Inches ---		---- Feet ----	
1	0.36a[4]	0.31a	2.00a	2.13a	0.46a	0.39a	2.58a	3.06a	0.40a	0.34a	1.84a	1.95a	0.23a	0.27a	1.98a	2.05a
2	.37a	.31a	2.18b	2.05a	.37a	.37a	2.68a	2.64a	.42a	.33a	2.15b	1.88a	.28a	.26a	1.98a	2.19a

[1]All means are least square means. Diameter growths are adjusted for diameter at beginning of the study and height growths are adjusted for height at the beginning of the study.
[2]Treatment 1 = no fertilizer, 2 = 200 lb N/acre.
[3]Time since treatment in years. There are no significant differences ($p \leq 0.05$) in the means between time periods.
[4]Different letters following means indicate significant differences ($p \leq 0.05$) between treatments.

between the periodic annual diameter growth means for Douglas-fir for either the first or second 5 years after treatment.

TREE SIZE

At DCEF, nitrogen fertilization did not significantly influence tree size of the entire mixed stand (table 4). No significant differences ($p \leq 0.05$) in either diameter or height were detected among the treatments 10 years after fertilization. The grand fir fertilized with 400 lb per acre had a mean diameter 15 percent larger than the unfertilized grand fir, and those fertilized with 200 lb of nitrogen per acre were 12 percent larger than unfertilized grand fir. But no differences in mean heights were found between the treatments of grand fir at the end of 10 years.

There were also no differences in mean heights or mean diameters between the fertilized and unfertilized trees for the entire stand at PREF (table 5) 10 years after fertilization. Among the species at PREF, the only significant difference in mean diameter 10 years after treatment was for western white pine. In that case, the unfertilized trees had a larger diameter mean than the fertilized ones. No differences in mean heights or diameters existed 10 years after treatment for either western larch or Douglas-fir.

DISCUSSION

The application of nitrogen fertilizer in the form of urea to young stands of mixed conifers growing on the *Tsuga heterophylla/Pachistima myrsinites* habitat type in northern Idaho does not appear to be that beneficial. Growth responses were highly variable and short-lived. For the most part, the only significant growth response to the application of nitrogen fertilizer occurred on grand fir at the DCEF study site. The results were even less impressive at the PREF site, where only a moderate height growth response to fertilizer was noted. In addition, at PREF the fertilized western white pines were growing more slowly than unfertilized trees.

From these results, it appears that nitrogen was not limiting at either location. Because both are good growing sites with deep soils and good organic reserves, the sites probably have adequate nitrogen available. In addition, the stand cleaning that occurred prior to the fertilization was done in a timely manner, resulting in a uniformly spaced stand of dominant and codominant trees, each having adequate growing space. This probably resulted in a microenvironment for each tree that had sufficient nitrogen for good growth and development of the species present.

The exception to poor growth responses from application of fertilizer was grand fir. At DCEF, grand fir responded well, but with a duration of less than 10 years. Grand fir is a shade-tolerant, late-successional species compared to the white pine and Douglas-fir that also occupy these sites. Grand fir may be similar to other late-successional species in that it can tolerate low levels of soil nitrogen, but may be more nitrogen demanding during aggressive growth. The amplitude of its growth response curve to nitrogen nutrition may be high over a wide range of nitrogen levels. If grand fir could become nitrogen demanding, it would increase its growth rates when nitrogen fertilizer is applied under good growing conditions. In contrast, a species such as western white pine may have a growth response curve with a low amplitude, making it tolerant to a narrow range in levels of nitrogen. Therefore, on a good site, western white pine would be less likely to respond to fertilizer than grand fir.

Although this study adds to the literature on fertilization of forest stands in the Northern Rocky Mountains, it continues to show that a wide range of growth responses can be expected. On good sites in northern Idaho, application of fertilizer to grand fir appears to be of some value, but application to other species does not appear to be warranted. Additional work on poor sites is currently under way.

Table 4.—Diameter at breast height (d.b.h.), and height means by treatment for all trees and for grand fir at Deception Creek Experimental Forest

Treatment	1972 d.b.h.	1982 d.b.h.	1982 adj. d.b.h.[1]	1972 height	1982 height	1982 adj. height[1]
	Inches			*Feet*		
			All species			
1[2]	1.3	4.1	4.3a[3]	10.0	22.9	23.8a
2	1.5	4.8	4.7a	11.1	26.1	25.6a
3	1.5	5.0	4.8a	11.0	26.1	25.4a
			Grand fir			
1	1.3	3.9	4.1a	9.7	22.2	22.4a
2	1.5	4.7	4.6b	10.7	27.3	27.1a
3	1.5	4.8	4.7b	10.5	27.7	27.6a

[1]These means are least square means. Diameters are adjusted for diameter at the beginning of the study and heights are adjusted for height at the beginning of the study.
[2]Treatment 1 = no fertilizer, 2 = 200 lb N/acre, 3 = 400 lb N/acre.
[3]Different letters following means indicate significant differences ($p \leq 0.2105$) between treatments.

Table 5.—Diameter at breast height (d.b.h.) and height means by treatment and species at Priest River Experimental Forest

Treatment	1972 d.b.h.	1982 d.b.h.	1982 adj. d.b.h.[1]	1972 height	1982 height	1982 adj. height[1]
	Inches			*Feet*		
			All species			
1[2]	3.2	6.4	6.6a[3]	20.9	41.1	42.1a
2	3.4	6.7	6.7a	22.4	43.5	42.8a
			Western white pine			
1	3.4	7.7	7.9a	20.8	49.0	49.4a
2	3.5	7.2	7.2b	21.2	47.9	47.3a
			Western larch			
1	3.0	5.4	5.6a	24.1	44.0	45.0a
2	3.2	5.9	5.9a	25.5	46.1	45.9a
			Douglas-fir			
1	3.6	7.3	7.2a	20.8	39.7	40.1a
2	3.4	7.1	7.3a	21.2	41.5	41.3a

[1]These means are least square means. Diameters are adjusted for diameter at the beginning of the study and heights are adjusted for height at the beginning of the study.
[2]Treatment 1 = no fertilizer, 2 = 200 lb N/acre.
[3]Different letters following means indicate significant differences ($p \leq 0.05$) between treatments.

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Ten-year results show initial short-lived increase in growth at two locations where nitrogen fertilizer in the form of urea was applied to young stands of mixed conifers in northern Idaho. In the second 5 years after treatment there were no further significant ($p \leq 0.05$) increases between the fertilized and unfertilized trees in either diameter or height growth. Grand fir (*Abies grandis*) responded better in the first 5 years than any other species, while western white pine (*Pinus monticola*) and western larch (*Larix occidentalis*) showed no evidence of response during the 10-year study.

KEYWORDS: fertilization, western white pine, grand fir, western larch, Douglas-fir, diameter growth, height growth

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